CLAIMS

What is claimed is:

1. A system for performing time delay estimation of signals propagating through an environment, comprising:

one or more sensors configured to receive a plurality of signals; and

a time delay estimator operative to measure time delays between multiple pairs of the plurality of signals, thereby generating time delay estimation data from the measured time delays,

wherein at least some of the time delays between the multiple pairs of signals are measured at different points in time.

2. The system of claim 1 wherein, in the event a degree of noise accompanies the multiple pairs of signals, at least some of the noise is non-correlated.

3. The system of claim 1 further including a data analyzer operative to analyze the time delay estimation data, to generate a statistical distribution of the time delay estimates from the time delay estimation data, and to calculate at least one of the mean, the median, and the mode of the time delay estimation distribution.

4. The system of claim 1 wherein the one or more sensors are configured to receive a plurality of successive signals including multiple pairs of successive signals.

5. The system of claim 4 wherein the system comprises a passive time delay estimation system.

6. The system of claim 1 wherein the plurality of signals propagate through a predetermined transmission medium within the environment, the predetermined transmission medium being one of a fluid, the earth, and living tissue.

7. The system of claim 1 wherein the time delay estimator includes a signal processor operative to perform one or more preprocessing techniques on one or more of the plurality of signals to facilitate a determination of the temporal location of the one or more signals.

8. The system of claim 7 wherein the temporal location of the one or more signals corresponds to a prominent feature of the one or more signals, the prominent feature being one of a signal peak, a signal valley, a signal energy, and a signal zero crossing.

9. The system of claim 7 wherein the preprocessing techniques include at least one of a first technique including determining an absolute value of at least one of the plurality of signals, a second technique including match filtering at least one of the plurality of signals, and an instantaneous envelope detection technique.

10. The system of claim 3 wherein the statistical distribution of the time delay estimates comprises a plurality of bins, the plurality of bins including a central bin, and wherein at least one first time delay estimate is associated with the central bin and multiple second time delay estimates are distributed among remaining ones of the bins.

11. The system of claim 10 wherein the multiple second time delay estimates are substantially uniformly distributed among remaining ones of the bins.

12. The system of claim 1 wherein the plurality of signals comprises one of sonar signals, seismic signals, ultrasonic signals, acoustic signals, and electromagnetic signals.

13. The system of claim 1 further including a beamformer configured to receive representations of the plurality of signals, and to provide beams corresponding to the plurality of signals to the time delay estimator.

14. A system for performing time delay estimation of signals propagating through an environment, comprising:

a transmitter configured to transmit multiple signals through the environment, wherein the transmitted signals travel through the environment until they strike at least one object, thereby generating multiple signals reflected from the object;

one or more sensors configured to receive the multiple reflected signals; and

a time delay estimator operative to receive representations of the transmitted signals, to measure time delays between multiple pairs of signals, each pair comprising a respective reflected signal and a representation of a respective transmitted signal, thereby generating time delay estimation data from the measured time delays,

wherein at least some of the time delays between the multiple pairs of signals are measured at different points in time.

15. The system of claim 14 wherein, in the event a degree of noise accompanies the reflected signals, at least some of the noise is non-correlated.

16. The system of claim 14 further including a data analyzer operative to analyze the time delay estimation data, to generate a statistical distribution of the time delay estimates from the time delay estimation data, and to calculate at least one of the mean, the median, and the mode of the time delay estimation distribution.

17. The system of claim 14 wherein the system comprises an active time delay estimation system.

18. The system of claim 14 wherein each transmitted signal comprises a sonar ping, and each reflected signal comprises a sonar echo.

19. The system of claim 14 wherein the multiple transmitted signals propagate through a predetermined transmission medium within the environment, the predetermined transmission medium being one of a fluid, the earth, and living tissue.

20. The system of claim 14 wherein the time delay estimator includes a signal processor operative to perform one or more preprocessing techniques on one or more of the reflected signals to facilitate a determination of the temporal location of the one or more reflected signals.

21. The system of claim 20 wherein the temporal location of the one or more reflected signals corresponds to a prominent feature of the one or more reflected signals, the prominent feature being

one of a signal peak, a signal valley, a signal energy, and a signal zero crossing.

22. The system of claim 20 wherein the preprocessing techniques include at least one of a first technique including determining an absolute value of at least one of the plurality of signals, a second technique including match filtering at least one of the plurality of signals, and an instantaneous envelope detection technique.

23. The system of claim 16 wherein the statistical distribution of the time delay estimates comprises a plurality of bins, the plurality of bins including a central bin, and wherein at least one first time delay estimate is associated with the central bin and multiple second time delay estimates are distributed among remaining ones of the bins.

24. The system of claim 23 wherein the multiple second time delay estimates are substantially uniformly distributed among remaining ones of the bins.

25. The system of claim 14 wherein the plurality of signals comprises one of sonar signals, seismic signals, ultrasonic signals, acoustic signals, and electromagnetic signals.

26. The system of claim 14 further including a beamformer configured to receive representations of the reflected signals, and to provide beams corresponding to the reflected signals to the time delay estimator.

27. A method of performing time delay estimation of signals propagating through an environment, comprising the steps of:

receiving a plurality of signals by one or more sensors;

measuring time delays between multiple pairs of the plurality of signals by a time delay estimator; and

generating time delay estimation data from the measured time delays by the time delay estimator,

wherein at least some of the time delays between the multiple pairs of signals are measured at different points in time.

28. The method of claim 27 wherein, in the event a degree of noise accompanies the multiple pairs of signals, at least some of the noise is non-correlated.

29. The method of claim 27 further including the steps of analyzing the time delay estimation data by a data analyzer, generating a statistical distribution of the time delay estimates from the time delay estimation data, and calculating at least one of the mean, the median, and the mode of the time delay estimation distribution.

30. The method of claim 27 wherein the receiving step includes receiving a plurality of successive signals including multiple pairs of successive signals.

31. The method of claim 30 wherein the system comprises a passive time delay estimation system.

32. The method of claim 27 wherein the plurality of signals propagate through a predetermined transmission medium within the environment, the predetermined transmission medium being one of a fluid, the earth, and living tissue.

33. The method of claim 27 further including the step of performing one or more preprocessing techniques on one or more of the plurality of signals by a signal processor included in the time delay estimator, thereby facilitating a determination of the temporal location of the one or more signals.

34. The method of claim 33 wherein the temporal location of the one or more signals corresponds to a prominent feature of the one or more signals, the prominent feature being one of a signal peak, a signal valley, a signal energy, and a signal zero crossing.

35. The method of claim 33 wherein the preprocessing techniques include at least one of a first technique including determining an absolute value of at least one of the plurality of signals, a second technique including match filtering at least one of the plurality of signals, and an instantaneous envelope detection technique.

36. The method of claim 29 wherein the statistical distribution of the time delay estimates comprises a plurality of bins, the plurality of bins including a central bin, and wherein at least one first time delay estimate is associated with the central bin and multiple second time delay estimates are distributed among remaining ones of the bins.

37. The method of claim 36 wherein the multiple second time delay estimates are substantially uniformly distributed among remaining ones of the bins.

38. The method of claim 27 wherein the plurality of signals comprises one of sonar signals, seismic signals, ultrasonic signals, acoustic signals, and electromagnetic signals.

39. The method of claim 27 further including the steps of receiving representations of the plurality of signals by a beamformer, and providing beams corresponding to the plurality of signals to the time delay estimator.

40. A method of performing time delay estimation of signals propagating through an environment, comprising the steps of:

transmitting multiple signals through the environment by a transmitter, wherein the transmitted signals travel through the environment until they strike at least one object, thereby generating multiple signals reflected from the object;

receiving the multiple reflected signals by one or more sensors;

receiving representations of the transmitted signals by a time delay estimator;

measuring time delays between multiple pairs of signals by the time delay estimator, each pair comprising a respective reflected signal and a representation of a respective transmitted signal; and

generating time delay estimation data from the measured time delays by the time delay estimator,

wherein at least some of the time delays between the multiple pairs of signals are measured at different points in time.

41. The method of claim 40 wherein, in the event a degree of noise accompanies the reflected signals, at least some of the noise is non-correlated.

42. The method of claim 40 further including the steps of analyzing the time delay estimation data by a data analyzer,

generating a statistical distribution of the time delay estimates from the time delay estimation data, and calculating at least one of the mean, the median, and the mode of the time delay estimation distribution.

43. The method of claim 40 wherein the system comprises an active time delay estimation system.

44. The method of claim 40 wherein each transmitted signal comprises a sonar ping, and each reflected signal comprises a sonar echo.

45. The method of claim 40 wherein the multiple transmitted signals propagate through a predetermined transmission medium within the environment, the predetermined transmission medium being one of a fluid, the earth, and living tissue.

46. The method of claim 40 further including the step of performing one or more preprocessing techniques on one or more of the reflected signals by a signal processor included in the time delay estimator, thereby facilitating a determination of the temporal location of the one or more reflected signals.

47. The method of claim 46 wherein the temporal location of the one or more reflected signals corresponds to a prominent feature of the one or more reflected signals, the prominent feature being one of a signal peak, a signal valley, a signal energy, and a signal zero crossing.

48. The method of claim 46 wherein the preprocessing techniques include at least one of a first technique including determining an absolute value of at least one of the plurality of signals, a

second technique including match filtering at least one of the plurality of signals, and an instantaneous envelope detection technique.

49. The method of claim 42 wherein the statistical distribution of the time delay estimates comprises a plurality of bins, the plurality of bins including a central bin, and wherein at least one first time delay estimate is associated with the central bin and multiple second time delay estimates are distributed among remaining ones of the bins.

50. The method of claim 49 wherein the multiple second time delay estimates are substantially uniformly distributed among remaining ones of the bins.

51. The method of claim 40 wherein the plurality of signals comprises one of sonar signals, seismic signals, ultrasonic signals, acoustic signals, and electromagnetic signals.

52. The method of claim 40 further including the steps of receiving representations of the reflected signals by a beamformer, and to provide beams corresponding to the reflected signals to the time delay estimator.

53. A method of performing time delay estimation of signals propagating through an environment, comprising the steps of:

receiving a plurality of signals by one or more sensors;

estimating time delays between multiple pairs of the plurality of signals by a time delay estimator;

generating time delay estimation data by the time delay estimator;

generating a statistical distribution of the time delay estimation data by a data analyzer;

calculating a first statistical estimate of time delay from the statistical distribution of the time delay estimation data by the data analyzer;

determining a next set of boundaries of the time delay estimation distribution;

removing at least one time delay estimate disposed outside of the boundaries from the time delay estimation distribution;

calculating a second statistical estimate of time delay from the statistical distribution of the time delay estimation data by the data analyzer; and

in the event the difference between the second statistical estimate and the first statistical estimate is greater than a predetermined threshold value, repeating the determining step, the removing step, and the second calculating step.

54. The method of claim 53 wherein the first and second statistical estimates are one of the mean, the median, and the mode of the distribution.

55. The method of claim 53 further including the step of performing one or more preprocessing techniques on one or more of the plurality of signals by a signal processor, thereby facilitating a determination of the temporal location of the one or more signals.

56. The method of claim 55 wherein the temporal location of the one or more signals corresponds to a prominent feature of the one or more signals, the prominent feature being one of a signal peak, a signal valley, a signal energy, and a signal zero crossing.

57. The method of claim 55 wherein the preprocessing techniques include at least one of a first technique including determining an absolute value of at least one of the plurality of signals, a second technique including match filtering at least one of the plurality of signals, and an instantaneous envelope detection technique.

58. The method of claim 53 wherein each one of the plurality of signals comprises a sonar echo.

59. The method of claim 53 wherein the plurality of signals propagate through a predetermined transmission medium within the environment, the predetermined transmission medium being one of a fluid, earth, and living tissue.

60. The method of claim 53 wherein the plurality of signals comprises one of sonar signals, seismic signals, ultrasonic signals, acoustic signals, and electromagnetic signals.

61. A method of performing time delay estimation of signals propagating through an environment, comprising the steps of:

receiving multiple sets of signals by a plurality of sensors, each signal set comprising a plurality of signals;

temporally aligning the multiple sets of signals;

calculating the mean energy of the signals received by each sensor, thereby generating a mean signal energy distribution;

identifying one or more peaks within the mean signal energy distribution based on a predetermined threshold;

defining a respective temporal window around each peak; and

calculating a statistical estimate of time delay corresponding to each respective peak, the statistical estimate

being calculated from the mean signal energy distribution within each temporal window around the respective peak.

62. The method of claim 61 wherein the statistical estimate is one of the mean, the median, and the mode of the distribution within each temporal window.

63. The method of claim 61 wherein the step of temporally aligning the multiple sets of signals includes applying a motion estimation and correction technique for each set of signals.

64. The method of claim 61 wherein each signal comprises a sonar echo.

65. The method of claim 61 wherein the plurality of signals propagate through a predetermined transmission medium within the environment, the predetermined transmission medium being one of a fluid, earth, and living tissue.

66. The method of claim 61 wherein the plurality of signals in each signal set comprises one of sonar signals, seismic signals, ultrasonic signals, acoustic signals, and electromagnetic signals.